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## *FINAL REPORT*

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# DEVELOPMENT OF NEW LONG-FIBRE PROCESSED ALFALFA PRODUCTS

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# Development of New Long-Fibre Processed Alfalfa Products

## Final Report

December 2001

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# Final Report

## A. Abstract

The objective of this project was to develop new long fibre alfalfa products for the export market. At the time that this project was initiated processed alfalfa products were receiving strong competition from European and U.S.A. products and Canadian processors were looking toward longer fiber products to compete with hay in the Asian market. It was found early in this project that the new long fiber products were relatively unpalatable and difficult to handle and transport. A series of seminars were presented in Japan and Korea to support traditional Canadian pellet and cube products. A major presentation was made at the International Green Crop Driers' Conference in Canmore, Alberta. The Canadian Dehy Association has reduced its activity and is combining some of its efforts with those of the Canadian Hay Association. Some of the quality problems with Canadian dehy products such as overheating have largely been corrected by the processors. Dehy and sun cured alfalfa is being incorporated into other products such as the pea canola seed blends containing up to 65% dehy. This product is produced by Oleet Inc. near Regina and marketed by Werner Agra Ltd. Future research should be directed toward support of additional forage crops such as timothy and oat forage marketed as compressed bales.

## B. Executive Summary

The objective of this project was to develop new long fibre products for the export market. Traditionally Canada has exported dehy alfalfa pellets and cubes and although Canada dominates the dehy pellet market it has relatively a small share of the alfalfa cube and compressed hay market. Early in this project long fiber cubes were evaluated and found unsatisfactory due to poor palatability and handling characteristics. Dehy chops were also evaluated. They consist of alfalfa hay chopped to approximately 4-inch length and compressed in bales and wrapped with a net. This product was relatively expensive to produce, was dry and dusty, and both difficult and expensive to transport. The palatability of this product was poor compared to long hay.

The direction of the project changed somewhat to include evaluation of blended products containing alfalfa. One of these is now marketed in significant amounts. This is a product consisting of an extruded pea canola seed blend with between 5 and 65% alfalfa included in the final pelleted product. This product is produced by Oleet Inc., Regina, Saskatchewan and marketed in several ways with most of the Asian marketing being done by Werner Agra Ltd.

A number of technical presentations were developed to support the Canadian alfalfa industry. One of these was presented at the International Green Crop Driers' Conference in Canmore, Alberta with seminars also being presented in Korea and Japan. Late in 2001 two presentations were made to the combined technical meeting of the Canadian Dehy Association and the Canadian Hay Association.

The organization of the forage industry in western Canada has changed greatly in the past year. The Canadian Dehy Association no longer has a full time manager although the organization continues to exist. The Canadian Hay Association focuses on alfalfa and timothy exports and now holds combined technical sessions and an annual meeting with the Canadian Dehy

Association. Both of these organizations have requested that the University of Saskatchewan continue to provide technical support both in product evaluation and in market development. Any further funding of projects for forage evaluation and market development should focus on some of the newer crops such as timothy and could also include development of technical information on oat forage as an export product. Some evaluation of alfalfa forage using some of the newer laboratory methods may be useful for market development of compressed alfalfa hay products.

**C. Technical Report**

The objective of this project was to develop new long fibre alfalfa products for the export market. At the time of this project application processed alfalfa products were receiving strong competition from European and U.S. products and Canadian processed products were also losing market share to both alfalfa hay and timothy products in baled compressed form. The Canadian industry was actively investigating chopped compressed baled products for the export market. Canada remains the major supplier of dehydrated alfalfa products to the Japanese market and has a minor but significant share of the cube market. During the course of this project the western Canadian processed alfalfa industry has gone through a period of turmoil and restructuring. The chopped compressed products that appeared promising several year ago have not proven to be satisfactory and are not gaining significant market share compared to compressed long forage.

The four progress reports submitted to this point trace a number of changes in direction of the research to support the western Canadian and Saskatchewan alfalfa industry. In Progress Report #1 (September 1999) studies were underway in which chewing and rumination activity in cows fed processed and long forage were being evaluated. It became from this work that in western Canada lack of fibre and lack of forage was not a serious problem, in fact excessive effective fibre may limit production. At this time several major players in the industry were showing interest in various processed products containing peas and whole canola that also contained dehydrated alfalfa. Just after the first progress report was submitted the Fifth International Green Crop Driers' Conference was held in Canmore, Alberta. Appendix I contains a paper presented by David Christensen at that conference which summarized research on processed alfalfa products to that time. This paper contained a summary of over 20 years research funded by the alfalfa industry, the federal government, and the governments of Saskatchewan and Alberta. This research has demonstrated the value of processed alfalfa products in many feeding situations both in the Asian and Canadian markets. It also pointed out problems in quality control in the industry and a lack of uniformity in palatability of the processed products either due to physical characteristics (hardness) or due to overheating of the products.

Progress Report #2 contained a summary of research trials in which alfalfa hay, alfalfa cubes and pellets were compared. As in a number of other trials the inclusion of alfalfa pellets gave a slight increase in milk yield compared to alfalfa hay. That report also contained a paper prepared for the alfalfa industry on new strategies for effective utilization of dehydrated alfalfa and other processed alfalfa products. This paper was used as the basis for further market development initiatives by the Canadian Dehy Association.

Progress Report #3 contained a PowerPoint presentation that was used by David Christensen in market development seminars in Japan and Korea. There was also a summary of research

comparing palatability and intake of a new long fibre form of cubes compared to hay. The intake of the cubes was unsatisfactory compared to a good quality hay.

Progress Report #4 (February 2001) referred to a project undertaken by Korvin Olfert with support from Sask Water on determining nutritive value of alfalfa at various stages of maturity. Mr. Olfert is taking courses at the University of Minnesota and final results of this phase of the work will not be available until late February 2002. Research on availability of amino acids in alfalfa hay and dehy pellets is included in Dawn Loveday's project, however, this work is not yet complete. There will be no further cost to the project of either the Olfert or Loveday work as that will be completed using either industry or Strategic ADF funds.

Recent research activity is summarized in Appendix II. This paper contains chemical composition and rumen degradability information on alfalfa pellets and cubes. Samples from a variety of commercial sources were included in this evaluation. The detailed laboratory analyses were designed to give information that could be used in models such as the Cornell Net Carbohydrate and Protein System or the new US-NRC Dairy Requirement model. It was concluded that differences in chemical composition and rumen degradability among the three alfalfa products were mainly due to differences in stage of maturity. This paper was published in the Journal of the Science of Food and Agriculture which has a broad worldwide distribution.

Over the past 25 years research projects on alfalfa products have been mainly in response to industry needs and questions or to provide more basic information on rumen fermentation palatability and digestion of products. The industry input was often through the Canadian Dehy Association. The Canadian Dehy Association no longer has a full time director, however, the organization remains in existence and has kept in contact with David Christensen for market development and research initiative strategies. For the past two years the Canadian Dehy Association and the Canadian Hay Association have held joint annual meetings in November. I was asked to make two presentations to joint technical sessions for the two organizations. A summary and PowerPoint presentation of each of these talks is attached.

Appendix III is a dairy nutrition update for forage producers. Dehy alfalfa and timothy hay were used in this presentation to illustrate new features of the NRC Dairy 2001 Model. This presentation also contained an explanation of why processed alfalfa products are failing to maintain market share in the Asian markets. A new type of ration has come into use in which non forage fibre is used to meet part of the requirement. These fibre sources include citrus pulp, whole cottonseed, cottonseed hulls, soybean hulls, tomato pulp, almond hulls, peanut hulls, and poultry litter. There is still a role for five to ten percent alfalfa or timothy forage in this type of ration, however, the pelleted products may have little or no role in this type of ration.

Appendix IV contains a summary and PowerPoint presentation on the second presentation entitled "The Role of Forages in Food Security and Safety". The executive members of both the Canadian Hay Association and the Canadian Dehy Association recognized the need for market evaluation over the next 10 to 20 years. This paper drew on FAO projections of demand for livestock products and the ability of Asian countries to produce forage. If meat and milk consumption continue to increase at the expected rate, assuming continued economic development, the forage base for cattle is inadequate in Asia. There is, therefore, a long term

positive outlook for forage products of some type in that market. This paper also covered the need for monitoring product quality and other undertakings such as identity, preservation of export products, genetic identification, segregation and traceability of the products. These two associations have suggested that seminars be held in Asia using material based on these two presentations.

Although the province of Saskatchewan has supported processed alfalfa product research for over 25 years, there is a need to consider a fundamental change in support for research on forages. There is little need for further evaluation of dehydrated alfalfa or alfalfa cubes. There may be some need to monitor their quality and to make use of new laboratory and animal evaluation from time to time. The emphasis, however, should be placed on activities that support the alfalfa hay and timothy hay export markets. There may be some opportunity for development of new products based on oat forage or other high forages. A very limited amount of forage research is being undertaken as part of the Strategic ADF nutrition program. When the Olfert and Loveday research is completed those results will be reported in the ADF Strategic Report, probably in January 2003. There is also some initial work on rates of fermentation of timothy and alfalfa forage reported in the ADF Strategic Program.

**E. Equipment**

No equipment was purchased for $500 or more.

**F. Project Development Materials**

The four appendixes attached contain material generated from this project.

**G. Project Photos**

Not applicable.

**H. Acknowledgement**

Support from the Saskatchewan Agricultural Development Fund has been made in the various presentations arising from this project.

**I. Expense Statement**

An expense statement will be provided by University of Saskatchewan

APPENDIX I

5th

# THE FIFTH INTERNATIONAL GREEN CROP DRIERS CONFERENCE

**October 4th - 8th, 1999**

**Canmore, Alberta, Canada**

# Proceedings

# Recent Research on Dehydrated Alfalfa Products in Canada

David Christensen
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## Introduction

Dehydrated alfalfa products have been and continue to be used as a source of vitamins and other nutrients as well as pigments in the poultry and livestock industry. For over 20 years they have played a significant role as a nutrient and fibre source dairy cattle ration. Processed alfalfa products have a relatively high and consistent nutrient content, plus a number of other advantages. These include convenience in handling, lower transportation and storage costs than long forage, minimal waste and spoilage during handling and feeding, uniform quality and suitable characteristics for use in a total mixed rations.

It has been well documented that dehydrated alfalfa products are a good source of rumen bypass protein. For the past 20 years undegraded intake protein (rumen bypass protein) has been emphasized in formulating rations for dairy cows at high levels of milk production. During this period herd milk production levels have steadily increased through genetic improvement as well as improved information on feeding systems and nutrient requirements. Herds now are expected to average 30 to 35 kgs of milk and many herds are now striving to reach herd averages of 40 kgs of milk daily. These higher levels of milk production have required a new look at the characteristics of dehydrated alfalfa products, their nutrient content and other characteristics in relation to the needs of high production dairy cows. This reexamination of dehydrated alfalfa products has included not only monitoring of nutrient composition, but also the adoption of new analytical methods that more fully describe protein and carbohydrate fractions. These more detailed analyses are incorporated into whole animal computer models that predict milk yield based on feed ingredient characteristics and a comprehensive description of the animal and herd environment. Detailed information on the amount and form of fibre and methods for describing

effective fibre in dairy cow rations has also become important. This aspect of fibre description is especially relevant to dehydrated alfalfa pellet and cube products.

Dehydration effects are associated with high temperature drying of both the leaf and stem material and in the past it was recognized that such drying conditions might have an undesirable effect on palatability. New methods have been developed for evaluating palatability of processed alfalfa products in order to remove barriers to suitable consumption levels by dairy cows. As information on nutrient requirements of dairy cows has evolved, it is now possible to include amino acid requirements in routine ration formulation. Alfalfa products have been examined to determine the amount and availability of amino acids and the extent to which processed alfalfa will support microbial protein production in the rumen. Research has also been conducted on the use of additives such as enzymes that may enhance either total digestibility of the cell wall material or will increase the initial rate of fermentation. Either of these effects may lead to higher milk production. As total mixed rations have been adopted, processing and particle size of forage in the total mixed ration has become an important consideration. Forage particle size is one of the determining factors in chewing and rumination time. Eating and rumination stimulate saliva production. This saliva is required to maintain rumen health and a high level of fermentation. Therefore, insufficient chewing time may lead to problems arising from low rumen pH such as rumen acidosis and low milk fat percentage. Excessive chewing time may be associated with a depression in total feed intake. This will result in lower milk production and loss of body condition. The purpose of this paper is to review and highlight these recent areas of Canadian research and to interpret them with respect to the use of dehydrated alfalfa products in rations for lactating dairy cows, targeting cows in early lactation and high levels of milk production.

**Composition**

The composition of alfalfa forage and dehydrated products has been studied extensively. Table 1 shows typical nutrient content of Canadian processed alfalfa products. In recent years net energy of lactation (NEl) has come into general use in North America. Acid detergent fibre (ADF) and neutral detergent fibre (NDF) have largely replaced crude fibre. In simplified feeding systems

ADF is used to estimate NEl and NDF is used to estimate maximum dry matter intake. Alfalfa is an excellent source of lysine, especially dehydrated alfalfa which retains a high proportion of the leaves which are rich in lysine content. Alfalfa protein contains a relatively high proportion of the sulphur containing amino acids, cysteine and methionine. Calcium and potassium are both abundant in alfalfa and trace mineral content will vary with soil conditions.

Crude protein is determined from the nitrogen content of alfalfa and this nitrogen content is converted to a crude protein value through multiplication by 6.25. This factor of 6.25 is based on the assumption that crude protein contains 16% nitrogen. Many studies have shown that in naturally dried alfalfa forage 25 to 30% of the crude protein passes through the rumen undegraded. In dehydrated products rumen bypass protein is increased to 55 to 60% of total protein. Until recently the main emphasis in formulating dairy rations was to consider both total crude protein content and rumen bypass protein percentage. This is no longer considered adequate to formulate rations for high levels of production and a more complex protein analysis system is used in combination with amino acid analysis.

Table 2 contains the average analysis of 6 dehy samples used in recent research trials at the University of Saskatchewan. These represent the new protein and carbohydrate analyses required for use in the new animal models, such as the 1999 Cornell-Penn-Miner Dairy Model. Similar analyses are required for the 1996 US-NRC Beef Model. It is anticipated that similar analyses will be required for the 2000 US-NRC Dairy Model. Acid detergent fibre insoluble crude protein is used as an index of unavailable cell wall material, while neutral detergent insoluble crude protein characterizes available cell wall protein or protein which has been bound to the cell wall during heating. In addition to the analysis shown in Table 2, it may be helpful to have further information on pectin content of alfalfa which has fermentation characteristics similar to those of starch. Alfalfa samples analyzed at the University of Saskatchewan averaged approximately 4% pectin. The new analyses are also used in calculating the protein fractions shown in Table 3. The calculation of these fractions uses an integration of rumen and digestion research over the past 30 years. As shown in this table, 25% of the protein of dehy alfalfa is in non protein nitrogen form which is instantly available. Only 3% remains in the B1 fraction which represents soluble cell content proteins. Due to heating during the dehydration process,

the B2 fraction is raised to 39% which is made up of insoluble cell content protein. About 9% of dehy protein is unavailable. Four carbohydrate fractions (Table 4) are used to describe cell wall and cell content carbohydrates. The amount and rate of degradation of these carbohydrate fractions are used in the computer model to estimate the amount of energy and carbohydrate available to support microbial growth. The carbohydrate fractions are important in estimating the amount of microbial protein that will be produced from rumen fermentation. The available amino acids from these microbes in combination with the available amino acids of feed origin passing through the rumen make up the metabolizable amino acid supply which is available to the animal for absorption in the small intestine.

**Meeting Amino Acid Requirements of Cattle**

The great nutritional improvement in poultry and swine productivity since the 1960s is based on knowledge of amino acid requirements and the amount and availability of amino acids in various feedstuffs. There have been many important milestones in animal nutrition. Other great milestones included discovery and commercial synthesis of vitamins and a greater understanding of mineral nutrition. Poultry and swine amino acid nutrition is dependent on the automated methods for amino analysis that became available in the 1960s. All of these great advances in animal nutrition have been available to ruminant nutritionists with the exception of reliable information on meeting amino acid requirements. This challenge is now being met with increasing reliability.

There are three major differences in ruminant metabolism from non-ruminants that make meeting amino acid requirements much more difficult. These include degradation of ration amino acids in the rumen and a partial reuse of the resulting amino acids and ammonia for microbial growth. Until recently, estimates of microbial protein production have been inadequate. A second major difference is the tremendous loss of amino acids as metabolic fecal nitrogen. This loss is related to abrasion of the gut from high fibre feeds and is approximately five times greater than the rate of loss in pigs and poultry. The impact of this loss on amino acid requirements has not yet been characterized with complete reliability. A third difference is the

ability of ruminants to recycle absorbed nitrogen products to the rumen through saliva or across the rumen wall. This recycling is mainly in the form of urea and ammonia.

Table 5 shows the amino acid requirements for maintenance and milk production by dairy cows. These estimates are based on the 1999 version of the CPM Dairy Model. Production of one kg of milk requires the absorption of 3.42 grams of lysine. Approximately 81% of this lysine is transferred to milk containing 3.2% protein. If the amount of lysine required for one kg of milk is used for comparison, the ratio of grams of other amino acids per gram of lysine used in milk synthesis can be calculated. For example (Table 5), for every 100 grams of lysine that the cow must absorb for milk production 32 grams of methionine are needed. Most amino acids are required in smaller amounts than lysine. Leucine is one exception where 137 grams of leucine are required for every 100 grams of lysine. Describing amino acids requirements in this fashion is sometimes called the ideal protein method.

The amounts of lysine in various feedstuffs are shown in Table 6. Almost all feeds contain less lysine as a percent of the protein than do rumen microbes. Cow's milk contains 8% lysine in the protein. Beef carcass contains the same or slightly higher level. Almost all feedstuffs contain less lysine in the protein than rumen microbes. Therefore, an essential feature of meeting the amino acid requirements for dairy cows at high production is to maximize rumen microbial growth. Although rumen microbes average about 8.5% lysine in the crude protein, there is tremendous variation in amino acid content of individual species of rumen microorganisms. Some species contain less than 6% lysine while others contain 13 to 14% lysine in their protein. Therefore, there can be considerable variation in the lysine content of rumen microbe organisms depending on conditions in the rumen that affect microbial growth. Although microbial protein resulting from rumen fermentation is a major source of amino acids, the maximum amount of microbial protein that can be produced daily is in the order of 2.5 to 2.8 kgs daily. This is insufficient to meet the protein requirements at very high levels of production where over 4 kgs of crude protein daily may be required in the diet.

The other source of amino acids, in addition to microbial protein, are amino acids of feed origin which pass through the rumen undegraded. These are the amino acids found in rumen bypass

protein (undegraded intake protein). Some proteins that have been widely used as bypass protein sources have a very poor lysine content. For example, corn gluten meal averages only 1.69 grams of lysine per 100 grams of crude protein. Although it is a very effective source of rumen bypass protein, it is a very poor source of the lysine required for milk synthesis. In contrast, alfalfa products are one of the better sources of lysine. Processed alfalfa products which contain 40 to 60% rumen bypass protein are especially effective in providing lysine for absorption and milk synthesis. Dehy alfalfa has a special role in that the fine particle size allows rapid fermentation of carbohydrate material in the rumen. It also allows protein to pass through the rumen unfermented supplying a high proportion of digestible essential amino acids. Table 7 shows the amino acid ratios in a number of feedstuffs. Isoleucine is the only amino acid in alfalfa which is not present in amounts greater than required in relation to lysine. Therefore, it may be beneficial to include a isoleucine source such as canola meal or a corn product in rations high in alfalfa content.

Computer models have evolved to the point where they are now useful in formulating dairy rations for amino acid content and balance. Although established concepts such as rumen bypass protein will continue to be used, they will gradually be replaced by improved methodology that estimates the total amount of amino acids available for absorption in the small intestine. The use of optimum carbohydrate and rumen available nitrogen sources will be used more in the future. The objective will be to find combinations of carbohydrates and proteins that sustain a high level of microbial growth at all times in the rumen.

**Effective Fibre**

Although the term "effective fibre" is commonly used in dairy cattle nutrition, it remains an elusive concept. It is well recognized that some measure of effective fibre is required for dairy cattle, beef cattle and other ruminants that are fed a high level of concentrate in combination with forage. This minimal level of effective fibre is required to maintain normal rumen function, to maintain the health of the animal and to ensure normal milk fat percentage. The terms "effective fibre", "physically effective fibre", "effective NDF" and "physically effective NDF" are all

attempts to describe the same essential characteristics of forage. For simplicity, the term "effective fibre" will be the main term used in this presentation.

For fibre to be effective it must have several essential characteristics. The first is that it be retained in the rumen long enough to be fermented. Fibre which is not fermented in the rumen but simply passes through the digestive tract is not truly effective. This is why the inclusion of inert material such as polyethylene chips or brushes have proved ineffective. Fermentation in the rumen converts carbohydrate to volatile fatty acids which provide at least 70% of the animal's energy. Available carbohydrates also are essential to support microbial growth. Fermentation of forage carbohydrates acts as a sustained release energy source to support microbial growth.

A second essential role of effective fibre is stimulation of chewing and rumination. Dairy cows may spend up to 4 hours per day in eating, chewing and activity associated with consumption of food. In addition to consumption of the feed, there is rumination or chewing of the regurgitated bolus that may take an additional 6 to 8 hours daily. It is during this eating and rumination activity that saliva production is at its highest rate. The rate of saliva production during eating and rumination has been studied to a limited degree. It is known that different feeds and different chewing rates will influence the rate of saliva production. This saliva is essential in providing a flow of buffer to the rumen, which is necessary to buffer the volatile fatty acids produced during fermentation. Periodic bouts of chewing and rumination may be more favorable than consumption of large meals to maintain desirable rumen conditions. It is desirable to avoid rumen conditions in which pH drops below 5.8 to 6. Low rumen pH inhibits microbial growth, changes the microbial population, and alters rumen fermentation products. This drop in pH can occur when large meals of highly fermentable feed are consumed or when chewing activity and production of saliva are suspended. Low rumen pH and the altered rumen fermentation accompanying it often results in lower milk fat percentage. A depression in feed intake may also occur.

A high fermentability of forage is associated with relatively low ADF and NDF content and also with a lower content of lignin in the ADF. There are large differences between forage species and ADF and NDF content. Alfalfa is relatively low in both, which is associated with its ready

fermentation in rumen. Tropical grasses tend to be very high in NDF content and in lignified ADF. High fibre content may be associated with longer rumination times, however, the disadvantage of these feeds is their slow rate of passage through the rumen and the lower levels of available and fermentable nutrients. Feed intake by cattle is limited by the rate at which NDF passes through the digestive tract. The limit is about 1.2% of body weight daily as NDF.

Particle size of the forage is a factor which complicates the evaluation of effective fibre. Small particles from finely ground forage pass through the rumen before there is sufficient time for fermentation to take place. It may take up to 1 to 2 hours for bacteria to attach themselves to fibre particles and a further 10 to 20 hours for maximal fermentation to take place. Research by Mertens and others has shown that particles less than 1.8 mm in length pass through the rumen at the same rate as the liquid portion of rumen contents. Rate of liquid outflow is 12 to 18% hourly. Table 8 contains a description of Mertens method for estimating physically effective NDF and a more recent method of calculation developed by Buckmaster and his associates. The method used to apply the Mertens method was published by the American Society of Agricultural Engineers as either method S424 or method S319.2. The Buckmaster method (Buckmaster et al. 1997) uses the Penn State Forage Particle Separator to separate forage into three fractions. These fractions are more than 19 mm, 8 to 19 mm and less than 8 mm. The method of calculating physically effective NDF by the Buckmaster method is also shown in Table 8. There is only limited research on the relationship of this measure of effective fibre to rumen pH and milk fat percentage. Kononoff found that 14% Type II peNDF in a total mixed ration would support normal milk fat percentage. It has been suggested that total mixed rations should contain 6 to 10% of forage longer than 19 mm, 30 to 50% between 8 and 19 mm and 40 to 60% less than 8 mm. Table 9 contains a description of Mertens effective fibre methods for a number of feedstuffs. As shown by Richardson (1998) in her undergraduate University of Saskatchewan thesis, alfalfa cubes contain approximately 24% effective fibre, or about the same amount as barley silage.

In most total mixed rations forage is chopped prior to incorporation into the total mixture. Although the forage being used in these rations may contain more than 60% physically effective fibre following chopping, the level is often much lower. As shown by Kononoff (1998) in his

University of Saskatchewan M.Sc. studies (Table 10), chopped alfalfa hay may contain 24 to 42% physically effective NDF using the Buckmaster method. This is similar to the peNDF in alfalfa cubes. In dairy production trials at the University of Saskatchewan (Tables 11 and 12) alfalfa cubes and pellets have maintained milk yield and milk fat percentage (Kirkpatrick et al. 1984, Fehr and Christensen, 1990).

In addition to type and characteristics and fermentability of forage and particle size, several other factors are of significance. The density of the forage determines whether or not it will sink to the bottom of the rumen or float in the fibre mat. It is in this mat that active forage fermentation takes place and boluses are formed for rumination. Highly digestible forage particles which sink to the bottom pass through the rumen providing nutrients for digesting and absorption in the small intestine. Another characteristic of interest is buffering capacity. Cell wall carbohydrate and mineral content may both contribute to buffering capacity, which is essential to maintain rumen pH above 6. Studies at the University of Saskatchewan have shown that alfalfa provides relatively high buffering capacity. It must be remembered, however, that feeds provide not more than 25% of total buffering capacity and that saliva production is essential to maintain good rumen fermentation conditions.

Processed alfalfa products provide a highly fermentable forage to maintain rumen fermentation and also provide digestible protein, carbohydrates and other nutrients which are available in the small intestine.

**Palatability of Alfalfa Products**

Alfalfa hay and silage are widely recognized as being highly palatable forages. However, it has been observed in research trials at the University of Saskatchewan and from comments by end users that not all batches of dehydrated alfalfa or alfalfa cubes are of high palatability. The University of Saskatchewan dairy herd total mixed ration has contained 2 kgs per cow daily of dehy pellets for a number of years. It has been observed that with some batches of dehy pellets a significant amount remains in the feed bunk or is consumed after most of the TMR has been consumed. It was suspected that drying conditions may play a role in reduction of palatability as

the occurrence of low intake was less common with suncured pellets. A series of trials were carried out using the University of Saskatchewan dairy herd as part of M.Sc. studies by Paterson (1996). An animal ethnologist (Harold Gonyou), familiar with the conduct of palatability research trials, assisted in developing methodology to test palatability and preference of processed alfalfa products.

In designing these studies on evaluation of alfalfa products a literature search was carried out to identify factors that may influence palatability. In 1970 Church defined palatability as "the relish which an animal shows when consuming any kind of food stuff or ration". In 1995 Forbes defined palatability as the overall impression of the food given by all animal senses. It cannot just be considered the quality of food, because it depends heavily on the experience and metabolic status of the animal in question. Palatability is often used to define the acceptance of a food when only one food is available.

Dietary preference, on the other hand, is the rejection or acceptance of feed when a group of palatable feeds are available. For example, a grazing animal may have access to a number of palatable grasses in a sward, however, the animal may be very selective and only consume certain grasses. It has been established that cattle respond to the four primary taste groups: sweet, salty, sour and bitter. In studies on the role of flavor additives, it has been found that monosodium glutamate and sodium chloride, when included in a cattle ration, may increase intake. It is felt that the role of smell in palatability and dietary preference may not be as critical as taste, but is an important factor in providing recognition cues to the animal. Cattle may associate smell with other desirable or undesirable factors which influence palatability and may alter diet selection. The sense of touch and the feel of the feeds in the mouth may alter feed intake and preference. Over time, touch receptors in the mouth may become adapted to the physical structure of a feedstuff. Coarse material may initially cause an undesirable sensation in the mouth. The animal may adapt to the physical structure of the rough feed and any reduction in feed intake may be temporary. Sight has relatively little effect on total feed intake. There may, however, be an effect of sight of feed on feed preference. Previous experience and adaptation is an important factor in feed recognition, palatability and feed preference. Past experience with a feedstuff and a familiarity with a feed may either be a positive or negative

factor in an animal's selection of a feedstuff in relation to another. The chemical components of a feedstuff may have some effect on palatability and preference. These may include the concentration of sugars or soluble carbohydrates, protein or nitrogen as well as individual minerals, carotene, vitamins, organic acids, tannins and silica. Specific effects of these nutrients have not yet been adequately described. Among the physical characteristics of feedstuffs it has been shown that fine particle size and dusty conditions may make the feed undesirable to ruminants.

In evaluating palatability and preference of alfalfa products, two methods were compared (Paterson 1996)). In these trials a group of 8 cows were individually housed in tie stalls, each with a fully enclosed feed bunk that was not readily visible to other cows and could not be accessed by adjacent animals. The method used was to feed these cows a total mixed ration with a morning feeding and an afternoon feeding approximately 9 hours later. During a 10 day adaptation period one kg of product was top dressed on each of the morning and afternoon allotments of total mixed ration. Each of the two products to be compared was top dressed on the TMR on alternate days. Therefore, each animal was exposed to each product for 5 days prior to preference testing.

Following this preliminary period, dairy cow preference was determined over a half hour period prior to the morning and afternoon feedings of total mixed ration on eight successive days. In each experiment two alfalfa products were compared. Two methods of feeding were employed. In one case the two feeds were offered side by side with the position of each feed being reversed at 5 minute intervals. Blue plastic tubs measuring approximately 50 x 40 cm were used throughout the trials. The second method of determining preference was the alternating choice procedure in which one of the two products was available to each cow for a five minute period and then that feed tub was removed and replaced with one containing the other product. Therefore in the side by side test, each cow had access to both feeds for two 30 minute periods daily whereas in the alternating procedure each cow had access to each feed for 15 minutes twice daily. The results of the first series of these trials are shown in Table 13 with the composition of the alfalfa pellets and cubes evaluated shown in Table 14.

In experiment 1 cows showed a definite preference for dehy pellets compared to suncured pellets. The dehy evaluated in this experiment was of exceptional high quality and had no odor that could be associated with overheating or burning of the alfalfa material. Experiment 2 using dehy cubes and suncured cubes showed the more expected pattern of slightly higher intake for the suncured product. The difference, however, was not statistically significant. In trials of this type, it has been reported that a 60% preference for one feed is considered to be both statistically and biologically different.

In experiments 3 and 4 cows preferred long cubes to short cubes. Long cubes averaged 2.72 cm in length and short cubes 1.73 cm. Cubes were 2.5 cm on each side. In experiment 4 in which the fines were removed from the cubes there was some increase in the intake of short cubes. The reason for the difference in preference could not be identified with certainty. However, the short cubes would have a higher proportion of rough end surface and it was felt that this might be a factor in determining preference. In order to examine this possibility further, hard cubes and soft cubes were compared. Soft cubes tend to have a rough surface on all sides compared to hard cubes. Hard cubes were 2.68 cm in length and soft cubes 2.53. The hard cubes had a hardness rating of .33 kN and the soft cubes .22 kN. Although the hard cubes were suitable for this testing purpose, they were not among the hardest cubes that have been examined. Hard cubes were preferred to the soft cubes by both the side by side and alternating methods. This finding should be regarded with caution as cubes which are 50 to 75% harder than those used in this test, have been found to impair intake.

These trials have shown definite differences in palatability and preference among processed alfalfa products. Odor resulting from high drying temperature and surface characteristics appear to be significant factors in determining palatability and preference of alfalfa products.

**Future Work**

Expansion of processed alfalfa product markets may depend on improved odor and physical characteristics of the products. There may also be an opportunity to produce cube or chopped products that have a slightly longer particle size that would bring the effective fibre level well up

into the range found for silage and chopped hay used in total mixed rations. Effective fibre contribution of processed alfalfa products should be more fully documented and adopted in ration formulation. Further development of both pellet and cube markets might be achieved by using processed alfalfa in combination with other products. These other products might include canola meal or other protein sources. They could also include cereal grain or grain legumes as a means of increasing the rumen fermentable carbohydrate. A variety of other byproduct materials including citrus pulp, beet pulp, almond hulls, apple pomice and brewing and distilling byproducts could be utilized. Research by Beauchemin and Rode (1999) on enzyme additives has also shown promise for improving rumen fermentation of alfalfa products leading to increased milk production. There may also be an opportunity to develop processed alfalfa products which are intermediate in size between dehy pellets and cubes currently on the market. The adoption of total mixed rations should expand the opportunity for appropriately processed alfalfa products with good palatability and physical handling characteristics.

**Table 1. Typical Nutrient Content of Canadian Processed Alfalfa Products (Dry Matter Basis)**

| | Dehy Alfalfa Pellets | Suncured Alfalfa Pellets | Alfalfa Cubes |
|---|---|---|---|
| Crude Protein, % | 18.85 | 17.0 | 17.0 |
| TDN, % | 66 | 61 | 61 |
| NEl, MCal/kg | 1.50 | 1.37 | 1.37 |
| Crude Fibre, % | 25 | 28 | 28 |
| ADF, % | 34 | 35 | 35 |
| NDF, % | 44 | 46 | 46 |
| Carotene, mg/kg | 180 | 58 | 58 |
| Lysine, % of Protein | 4.92 | 4.65 | 4.65 |
| Methionine, % of Protein | 1.53 | 1.39 | 1.39 |
| Cystine, % of Protein | 1.64 | 1.33 | 1.33 |
| Calcium | 1.6 | 1.5 | 1.5 |
| Phosphorus | 0.22 | 0.20 | 0.20 |
| Potassium | 2.40 | 2.35 | 2.35 |

**Table 2. University of Saskatchewan Analysis of Dehydrated Alfalfa Pellets[1] for Use in Milk Production Models (Dry Matter Basis)**

| | Dehy Pellets |
|---|---|
| Crude Protein, % | 20 |
| Soluble CP, % of CP | 28 |
| NPN, % of CP | 25 |
| NPN, % of Soluble CP | 90 |
| NDF Insoluble CP, % of CP | 32 |
| ADF Insoluble CP, % of CP | 8.6 |
| ADF, % | 31 |
| NDF, % | 43 |
| Acid Detergent Lignin, % of NDF | 19 |
| Total Carbohydrate % | 66 |
| Non Structural Carbohydrate, % | 30 |
| Starch, % of NSC | 3 |
| Physically Effective Fibre (pENDF) | 9 |

[1]Six samples
Mustafa, Christensen and McKinnon, American Society of Animal Science, July 1990

**Table 3. Protein Fractions and Their Degradation Rates**

| CPM Dairy Model Fractions | Description | Dehy Alfalfa Composition, % of CP | Degradation rate (% $h^{-1}$) |
|---|---|---|---|
| A | soluble non protein nitrogen and peptides | 25 | instantaneous |
| B1 | soluble proteins, cell contents | 3 | 200 - 300 |
| B2 | insoluble, cell contents | 39 | 5 - 15 |
| B3 | insoluble, cell wall | 24 | 0.1 - 1.5 |
| C | cell wall, unavailable, N bound to lignin | 9 | 0 |

*Adapted from the CPM Dairy Model

**Table 4. Carbohydrate Fractions and Their Degradation Rates**

| CPM Dairy Model Fractions | Description | Dehy Alfalfa Composition, % of DM | Degradation rate (%/h) |
|---|---|---|---|
| A | Soluble sugars | 29 | 200 - 350 |
| B1 | Starch, pectin, beta glucans | 1 | 20 - 40 |
| B2 | Insoluble available cell wall (NDF) | 17 | 2 - 10 |
| C | Unavailable cell wall (ADF lignin) | 9 | 0 |

*Adapted from the CPM Dairy Model

**Table 5. Amino Acid Requirements of Dairy Cows: 680 kg cows, 3 BCS; CPM Dairy Model, 1999**

| | Amounts of Absorbed Amino Acids | | | Amount for one kg of milk, g | Lysine Ratio for milk | Milk AA g/kg[1] | Percent Trans-ferred to milk |
|---|---|---|---|---|---|---|---|
| | Maint. g/day | Maint. and 40 kg milk | 40 kg milk 3.65% fat, 3.2% CP | | | | |
| Methionine | 7.2 | 50.6 | 43.4 | 1.08 | 32 | 0.77 | 71 |
| Lysine | 23.4 | 160.2 | 136.8 | 3.42 | 100 | 2.77 | 81 |
| Arginine | 24.2 | 155.5 | 131.3 | 3.28 | 96 | 1.15 | 35 |
| Threonine | 14.3 | 88.3 | 74 | 1.85 | 54 | 1.28 | 69 |
| Leucine | 26.4 | 213.7 | 187.3 | 4.68 | 137 | 3.22 | 67 |
| Isoleucine | 11.2 | 137.4 | 126.2 | 3.16 | 92 | 1.68 | 53 |
| Valine | 15.9 | 34.6 | 118.1 | 2.95 | 86 | 2.18 | 76 |
| Histidine | 9.1 | 58.4 | 49.3 | 1.23 | 36 | 0.91 | 74 |
| Phenylalanine | 12.9 | 88.2 | 75.3 | 1.88 | 55 | 1.68 | 89 |
| Tryptophan | 1.8 | 25.5 | 23.7 | 0.59 | 17 | 0.52 | 88 |

[1]US-NRC Tables of Feed Composition

**Table 6. Lysine Content of Feedstuffs**

| | % in Crude Protein |
|---|---|
| Alfalfa dehy, US-Canadian | 4.92 |
| Alfalfa dehy, Swine NRC | 4.59 |
| Alfalfa cubes, SK | 4.93 |
| Alfalfa hay, SK | 4.50 |
| Beet pulp, Swine NRC | 6.05 |
| Barley silage, Lacombe, SK | 5.00 |
| Corn silage | 2.13 |
| Timothy hay | 2.83 |
| Barley grain, NRC | 3.63 |
| Barley grain, SK | 3.24 |
| Corn grain, NRC | 3.13 |
| Canola meal, NRC | 5.84 |
| Canola meal, SK, raw | 4.52 |
| Pea seed, SK, raw | 6.46 |
| Pea seed, SK, micronized | 6.28 |
| SBM, NRC | 6.36 |
| Corn gluten meal, NRC | 1.69 |
| Wheat distillers grain, MB | 2.06 |
| Rumen microbes | 8.5 |
| Cows milk | 8.0 |
| Beef carcass | 8.5 |

Lysine values are from the 1998 Swine NRC requirement publication or from analyses carried out by the Manitoba feed analysis laboratory.

Milk lysine based on US-NRC Feed Composition was 8.67 g/100 g CP; and lysine in calf gain was estimated to be 2.13 g/100 g of live gain, based on the CPM Dairy Model.

**Table 7. Lysine Ratios for Lactating Dairy Cows**

| | Dehy Alfalfa | Barley Silage | Corn Silage | Barley Grain | Corn Grain | Soybean Meal | Corn Gluten Meal | Canola Meal Raw | Beet Pulp | Rumen Microbes |
|---|---|---|---|---|---|---|---|---|---|---|
| Methionine | 38 | 29 | 37 | 48 | 65 | 22 | 140 | 42 | 13 | 33 |
| Lysine | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Arginine | 91 | 33 | 88 | 132 | 142 | 115 | 189 | 110 | 61 | 85 |
| Threonine | 89 | 75 | 100 | 85 | 112 | 61 | 205 | 91 | 73 | 68 |
| Leucine | 138 | 127 | 300 | 188 | 381 | 121 | 1002 | 138 | 102 | 92 |
| Isoleucine | 66 | 65 | 123 | 95 | 108 | 72 | 244 | 61 | 60 | 72 |
| Valine | 93 | 105 | 150 | 127 | 150 | 75 | 274 | 73 | 86 | 75 |
| Histidine | 37 | 33 | 50 | 61 | 88 | 42 | 126 | 50 | 44 | 33 |
| Phenylalanine | 80 | 69 | 138 | 134 | 150 | 79 | 378 | 72 | 58 | 63 |
| Tryptophan | 37 | 27 | 5 | 27 | 23 | 22 | 30 | 41 | 19 | 20 |

**Table 8. Methods of Describing Effective Fibre**

| | |
|---|---|
| **Type 1 (Mertens)** | Physically Effective NDF (peNDF I)<br>= (DM larger than 1.18 mm) x % NDF in DM |
| **Type II (Buckmaster)** | Physically Effective NDF (peNDF II)<br>= (% of total NDF in particles longer than 19 mm) x 2<br>+ (% of total NDF in particles 8 to 19 mm) x 1<br>+ (% of total NDF in particles less than 8 mm) x 0.2 |

**Table 9. The peNDF[w] of Various Feeds**

| Feed | NDF (% DM) | % of DM retained on a 1.18 mm sieve | Type I (Mertens) peNDF[z] |
|---|---|---|---|
| Grass hay (long) | 65 | 98 | 63.7 |
| Legume hay (long) | 50 | 92 | 46.0 |
| Legume silage (course chop) | 50 | 82 | 41.0 |
| Legume silage (fine chop) | 50 | 67 | 33.5 |
| Dehydrated alfalfa cubes[x] | 47 | 50 | 23.5 |
| Barley silage[y] | 49 | 52 | 25.5 |
| Corn silage | 51 | 81 | 41.5 |
| Brewers grains | 46 | 18 | 8.3 |
| Barley, rolled[y] | 18.2 | 79.6 | 14.5 |
| Corn, ground | 9 | 48 | 14.5 |
| Canola meal[y] | 8.6 | 18.1 | 1.6 |
| Soybean meal | 14 | 23 | 3.2 |
| Wheat distillers grain[y] | 7.2 | 34.9 | 2.7 |
| Soybean hulls | 67 | 3 | 2.0 |

[w]adapted from Mertens (1997), referred to as Type I Physically Effective Neutral Detergent Fibre
[x]Richardson and Christensen (unpublished)
[y]Kononoff and Christensen (unpublished)
[z]Type I peNDF is calculated by multiplying NDF by the fraction retained on a 1.18 mm sieve

**Table 10. Physically Effective NDF in Alfalfa Forage (Based on 45% NDF in DM)**

| | Corn Silage | | Kononoff Alfalfa Hay Samples Bale Chopper Screen Size | | | Precube Chop Long Sample | Precube Chop Shortest Sample |
|---|---|---|---|---|---|---|---|
| Fraction | Short | Long | 25mm | 51 mm | 76/102 mm | | |
| more than 19 mm | 10 | 18 | 3 | 10 | 22 | 23 | 2 |
| 8 to 19 mm | 52 | 58 | 34 | 52 | 43 | 25 | 30 |
| less than 8 mm | 38 | 24 | 63 | 38 | 35 | 52 | 68 |
| peNDF (Buckmaster) | 35 | 44 | 24 | 36 | 42 | 37 | 22 |

Table 11. **Dehy Alfalfa Pellets as a Concentrate Ingredient**

| Item | Portion of concentrate replaced with dehydrated alfalfa | | | | |
|---|---|---|---|---|---|
| | 0% | 15% | 30% | 45% | SE |
| Milk yield, kg/day | 25.33 | 24.88 | 25.29 | 24.90 | .87 |
| Milk fat, % | 3.20 | 3.34 | 3.48 | 3.54 | .135 |
| Milk fat, kg/day | .77 | .78 | .85 | .87 | .042 |
| 4% fat-corrected milk (FCM) yield, kg/day | 22.0 | 21.6 | 23.5 | 23.0 | 1.90 |
| Persistency of fat-corrected milk yield, % | 89 | 81 | 88 | 84 | 2.50 |
| Total solids, % | 11.62 | 11.72 | 11.83 | 11.93 | .18 |
| Milk protein, % | 3.46 | 3.48 | 3.44 | 3.47 | .05 |
| Dry matter intake/100 kg of 4% FCM, kg | 99 | 97 | 95 | 99 | 3.62 |

Kirkpatrick, et al. 1984.

**Table 12. Milk Yield and Composition from Cows and First Lactation Heifers Fed 3 Kg of Alfalfa Product Dry Matter Per Day as a Portion of the Forage**

| | | Long Hay | Dehy Chops | 3/8" coarse pellets | 3/8" fine pellets | 1/4" pellets |
|---|---|---|---|---|---|---|
| Milk yield, kg/day | cows | 37.2 | 37.6 | 37.7 | 37.1 | 35.7 |
| | heifers | 27.7 | 27.9 | 27.5 | 26.8 | 28.4 |
| Milk fat, % | cows | 2.96 | 3.08 | 2.86 | 2.91 | 3.01 |
| | heifers | 3.57 | 3.51 | 3.46 | 3.57 | 3.47 |
| 4% FCM yield, kg/day | cows | 30.9 | 32.3 | 31.0 | 30.9 | 30.4 |
| | heifers | 25.8 | 25.8 | 25.0 | 24.8 | 26.2 |
| FCM yield, persistency, % | cows | 92.6 | 94.9 | 95.8 | 94.6 | 88.3 |
| | heifers | 94.7 | 100.6 | 96.8 | 99.2 | 96.2 |
| Milk protein, % | cows | 3.15 | 3.15 | 3.11 | 3.10 | 3.15 |
| | heifers | 3.32 | 3.39 | 3.40 | 3.40 | 3.39 |
| Feed DM/100 kg 4% FCM, kg | cows | 73.0 | 76.3 | 76.1 | 80.0 | 81.9 |
| | heifers | 73.0 | 76.1 | 79.6 | 78.0 | 72.8 |
| Bodyweight change, g/day | cows | -24 | +303 | +344 | +373 | +26 |
| | heifers | +44 | +650 | +350 | +369 | +84 |

Fehr and Christensen, 1990

**Table 13. Mean Daily DMI and Preference Percentage on the Side by Side and Alternating Preference Testing Evaluating the Palatability of Alfalfa Products.**

| | Intake (kg cow$^{-2}$ day$^{-1}$ | | Preference % | |
|---|---|---|---|---|
| | Side by Side | Alternating | Side by Side | Alternating |
| Experiment 1 | | | | |
| Dehy pellets | 1.96*a* | 1.95*a* | 68*a* | 59*a* |
| Suncured pellets | 0.98*b* | 1.36*b* | 33*b* | 41*b* |
| SEM[z] | 0.30 | 0.18 | 9 | 6 |
| Experiment 2 | | | | |
| Dehy cubes | 0.97 | 1.00 | 48 | 53 |
| Suncured cubes | 1.21 | 1.03 | 52 | 48 |
| SEM[z] | 0.26 | 0.18 | 13 | 10 |
| Experiment 3 (with fines) | | | | |
| Long cubes | 0.93*a* | 0.84*a* | 71*a* | 66*a* |
| Short cubes | 0.41*b* | 0.42*b* | 29*b* | 29*b* |
| SEM[z] | 0.18 | 0.08 | 15 | 4 |
| Experiment 4 (fines removed) | | | | |
| Long cubes | 1.19 | 1.12 | 60 | 56 |
| Short cubes | 0.83 | 0.95 | 40 | 45 |
| SEM[z] | 0.18 | 0.09 | 9 | 6 |
| Experiment 5 | | | | |
| Hard cubes | 1.52*a* | 1.47*a* | 65*a* | 55*a* |
| Soft cubes | 0.84*b* | 1.12*b* | 35*b* | 45*b* |
| SEM[z] | 0.18 | 0.12 | 6 | 5 |

*a-b* means followed by different letters in the same column within the same experiment are different ($P < 0.05$)
[z]standard error of the mean

**Table 14. Nutritional Characteristics of Alfalfa Products.**

| | Nutritional Component | | | | |
|---|---|---|---|---|---|
| | DM, % | CP, % of DM | NDF, % of DM | ADF, % of DM | Ca, % of DM |
| Experiment 1 | | | | | |
| Dehy pellets | 93 | 19.0 | 44 | 28 | 1.82 |
| Suncured pellets | 92 | 17.8 | 53 | 37 | 1.33 |
| Experiment 2 | | | | | |
| Dehy pellets | 92 | 18.8 | 43 | 31 | 1.51 |
| Suncured pellets | 91 | 16.0 | 46 | 36 | 1.15 |
| Experiment 3 | | | | | |
| Long cubes (with fines) | 92 | 15.7 | 51 | 38 | 1.27 |
| Short cubes (with fines) | 91 | 17.8 | 46 | 39 | 1.22 |
| Experiment 4 | | | | | |
| Long cubes (no fines) | 92 | 15.7 | 51 | 38 | 1.27 |
| Short cubes (no fines) | 91 | 17.8 | 46 | 39 | 1.22 |
| Experiment 5 | | | | | |
| Hard cubes | 92 | 16.7 | 50 | 39 | 1.25 |
| Soft cubes | 91 | 17.1 | 47 | 42 | 1.26 |

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# Chemical composition and ruminal degradability of lucerne (*Medicago sativa*) products

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**Abstract: A study was conducted to determine the chemical composition and *in situ* nutrient ruminal degradability of three lucerne products. These were dehydrated pellets, sun-cured pellets and cubes. Results of the chemical analysis showed that sun-cured pellets had the highest ($P < 0.05$) neutral and acid detergent fibre as well as total carbohydrate levels, followed by cubes and dehydrated pellets respectively. Crude protein (CP) content was highest ($P < 0.05$) for dehydrated pellets (204.3 g kg$^{-1}$), intermediate for sun-cured pellets (160.0 g kg$^{-1}$) and lowest for cubes (153.2 g kg$^{-1}$). Intermediately degradable CP (buffer-insoluble CP minus neutral detergent-insoluble CP) was the main protein fraction in the three products and was higher ($P < 0.05$) in cubes than in dehydrated and sun-cured pellets. Estimated net energy of lactation was highest ($P < 0.05$) for dehydrated pellets (5.9 MJ kg$^{-1}$), intermediate for cubes (5.23 MJ kg$^{-1}$) and lowest ($P < 0.05$) for sun-cured pellets (5.15 MJ kg$^{-1}$). Results of the *in situ* experiment indicated that dehydrated pellets had higher ($P < 0.05$) ruminal protein degradability than sun-cured pellets and cubes. The estimated ruminal escape protein values for dehydrated pellets, sun-cured pellets and cubes were 361, 420 and 498 g kg$^{-1}$ CP respectively. It was concluded that differences in chemical composition and ruminal degradability among the three lucerne products were mainly due to differences in stage of maturity. It was also concluded that the dehydration process failed to increase the ruminal escape protein value of dehydrated pellets relative to sun-cured pellets and cubes.**

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**Keywords:** dehydrated lucerne products; chemical characterisation; ruminal degradability

## INTRODUCTION

Lucerne (*Medicago sativa*) is a major source of dietary protein and energy for ruminants. Processed lucerne products have been widely used in ruminant rations in both meal and pellet forms.[1–3] Several forms of processed lucerne products are available. These include sun-cured pellets, cubes and dehydrated pellets. Dehydrated pellets are produced from lucerne cut at the late bud/early flowering stage and dehydrated at a temperature of 110–120 °C for 5 min or less.[4] Sun-cured pellets and cubes are produced from more mature hay that is either partly or completely field-dried before processing. The main difference between sun-cured pellets and cubes is the fact that cubes are made from coarsely chopped hay, while hay used to produce sun-cured pellets is ground and then processed into pellets.[4]

Several studies have shown that stage of maturity and processing such as steaming or oven heating of lucerne hay reduce ruminal degradability and improve protein utilisation by ruminants.[5,6] Because of differences in method of processing and stage of maturity, lucerne products are expected to have different ruminal nutrient degradability. Data on ruminal nutrient degradability for lucerne pellets and cubes are limited.

A new model has been developed to predict performance in cattle.[7] A major component of this model is the division of dietary protein into five fractions and dietary carbohydrate into four fractions based on the Cornell Net Carbohydrate and Protein System (CNCPS) as described by Sniffen *et al.*[8] The protein fractions include the buffer-soluble component, in which fraction A is non-protein nitrogen and fraction B1 (rapidly degradable) is buffer-soluble true protein. Fraction B2 (intermediately degradable) is the buffer-insoluble fraction that is not contained in the cell wall, while fraction B3 (slowly degradable) is neutral detergent-insoluble protein. Fraction C is not degraded by rumen microbes and is associated with acid detergent fibre. Carbohydrate is fractionated into fraction A (rapidly fermented sugars), fraction B1

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(intermediately degradable) consisting mainly of starch and pectins, fraction B2 (slowly degradable) which is available cell wall carbohydrate, and fraction C which is unavailable carbohydrate. No work has been published to define the different carbohydrate and protein fractions of different lucerne products based on the CNCPS. The objectives of this study were to determine the carbohydrate and protein fractions as well as ruminal nutrient degradability of dehydrated pellets, sun-cured pellets and cubes.

## MATERIALS AND METHODS

### Sample preparation and analysis

Samples ($n = 6$ each) of dehydrated lucerne pellets, sun-cured lucerne pellets and lucerne cubes derived from six different fields were provided by Alberta Dehydrators (Edmonton, Alberta, Canada). Prior to chemical analysis, subsamples (100 g) of each lucerne product were ground through a 1 mm screen using a hammer mill (Christie-Norris Laboratory Mill, size 8 in; Christie-Norris Ltd, Chelmsford, UK). Samples were then analysed for moisture (135 °C for 2 h), ash (600 °C for 3 h), ether extract (extraction with petroleum ether for 6 h), acid detergent fibre (ADF), acid detergent lignin (ADL) and crude protein (CP; Kjeldahl nitrogen × 6.25) according to AOAC standard procedures.[9] Neutral detergent fibre (NDF) was determined according to Van Soest *et al.*[10] Buffer-soluble protein and non-protein nitrogen were determined following the procedures of Licitra *et al.*[11] Neutral and acid detergent-insoluble protein were determined by analysing NDF and ADF residues respectively for Kjeldahl nitrogen.[9]

The equations of Sniffen *et al*[8] were used to fractionate carbohydrate, based on rates of degradation in the rumen, into rapidly degradable (A), intermediately degradable (B1), slowly degradable (B2) degradable and unavailable (C) fractions. True protein fraction B was estimated by subtracting non-protein nitrogen and acid detergent-insoluble protein from total CP.[8] The true protein fraction was then subfractionated, based on rates of protein degradation in the rumen, into rapidly degradable (B1), intermediately degradable (B2) and slowly degradable (B3) fractions.[8]

Total digestible nutrient and net energy of lactation values for dehydrated pellets, sun-cured pellets and cubes were estimated from ash, ether extract, CP, NDF, ADL, acid detergent-insoluble protein and neutral detergent-insoluble protein using the equation of Weiss *et al.*[12]

### *In situ* experiment

Equal portions (200 g) of the six samples of dehydrated pellets, sun-cured pellets and cubes were composited to obtain a single batch of each lucerne product. Samples were then ground through a 2 mm screen using a hammer mill. Two non-lactating Holstein cows fitted with flexible rumen cannulae were used for rumen incubations. The cows were fed twice daily with equal portions of lucerne hay at 15 g $kg^{-1}$ body weight. The cows were adapted to their feed over a 4 week period. Five grams of each lucerne product was weighed in duplicate into polyester bags (Model 03–37/24, 9 cm × 12 cm, 41 μm porosity; Sefar Canada, Scarborough, Ontario, Canada). The bags were then placed into polyester mesh bags (25 cm × 33 cm) and incubated in the rumen of each cow for 6, 12, 18, 24, 48, 72 and 96 h. Zero-time disappearance was estimated by washing duplicate bags in tap water. Following removal from the rumen, the bags were washed and handled as described by McKinnon *et al.*[13]

Residues from each polyester bag were ground and subjected to dry matter (DM) and CP analysis as described previously. The disappearance of DM and CP at each incubation time was calculated from the concentration of these nutrients in the original sample and the residues and was used to estimate ruminal kinetic parameters according to the equation of Ørskov and McDonald:[14]

$$p = a + b(1 - e^{-ct})$$

where $p$ is the ruminal disappearance at time $t$, $a$ is the soluble fraction (g $kg^{-1}$), $b$ is the slowly degradable fraction (g $kg^{-1}$) and $c$ is the rate at which the $b$ fraction is degraded (% $h^{-1}$). Ruminal effective degradability (ED) of DM and CP was estimated using the equation of Ørskov and McDonald:[14]

$$ED = a + bc/(c + k)$$

where $k$ is the ruminal particulate passage rate (5% $h^{-1}$).

### Statistical analysis

Data for the chemical composition were analysed as a completely randomised design (three treatments and six replicates) using the General Linear Model of SAS.[15] Data of the *in situ* polyester bag trial were analysed as a randomised complete block design where individual cows were used as blocks. Where applicable, means were separated at the 5% level of significance using the Student–Newman–Keul procedure.[16]

## RESULTS AND DISCUSSION

### Carbohydrate composition of lucerne products according to the CNCPS

Carbohydrate analysis and fractions of the lucerne products are shown in Table 1. Neutral and acid detergent fibre levels were highest ($P < 0.05$) for sun-cured pellets, intermediate ($P < 0.05$) for cubes and lowest ($P < 0.05$) for dehydrated pellets. However, dehydrated pellets had the highest ($P < 0.05$) level of ADL (g $kg^{-1}$ NDF), followed by sun-cured pellets and cubes respectively. Our ADL levels are within the range reported by NRC[7] for lucerne hay at different stages of maturity.

| | Pellets | | | |
|---|---|---|---|---|
| | Dehydrated | Sun-cured | Cubes | SEM[a] |
| *Carbohydrate analysis* | | | | |
| Neutral detergent fibre (NDF; g kg$^{-1}$ DM) | 430.2c | 556.4a | 508.8b | 3.44 |
| Acid detergent fibre (g kg$^{-1}$ DM) | 306.4c | 414.2a | 368.7b | 2.37 |
| Acid detergent lignin (g kg$^{-1}$ NDF) | 184.6a | 159.4b | 138.9c | 4.09 |
| Total carbohydrate (g kg$^{-1}$ DM) | 660.3c | 716.8a | 703.5b | 3.49 |
| Non-structural carbohydrate (NSC; g kg$^{-1}$ DM) | 296.3a | 212.5c | 236.5b | 4.26 |
| Starch (g kg$^{-1}$ NSC) | 29.5b | 42.0a | 24.5c | 0.85 |
| *Carbohydrate fractions (g kg$^{-1}$ DM)* | | | | |
| A (rapidly degradable) | 287.2a | 203.8c | 230.2b | 4.30 |
| B1 (intermediately degradable) | 9.0 | 9.0 | 6.0 | 0.00 |
| B2 (slowly degradable) | 173.3b | 291.7a | 297.3a | 5.62 |
| C (unavailable) | 190.5b | 212.8a | 169.5c | 4.4 |

**Table 1.** Carbohydrate analysis and fractionation of lucerne products according to the Cornell Net Carbohydrate and Protein System (DM basis)

Means in the same row with different letters are significantly different ($P < 0.05$).
[a] Pooled standard error of the mean.

Differences in fibre contents among the three lucerne products are likely due to the fact that dehydrated pellets are produced from material at an earlier stage of maturity than cubes or sun-cured pellets. Similar NDF and ADF values for dehydrated pellets were reported by Lintzenich *et al.*[3] Differences in cell wall content among the lucerne products were reflected in the non-structural carbohydrate level, which was highest ($P < 0.05$) for dehydrated pellets and lowest ($P < 0.05$) for sun-cured pellets (Table 1).

Fractionation of total carbohydrate based on rates of degradation in the rumen showed that rapidly degradable carbohydrate was higher ($P < 0.05$) in dehydrated pellets than in cubes and higher ($P < 0.05$) in cubes than in sun-cured pellets (Table 1). The values reported for rapidly degradable carbohydrate were similar to those reported for non-structural carbohydrate, indicating that organic acids and soluble sugars are the main components of non-structural carbohydrate in lucerne products.[8] Sun-cured pellets and cubes had a similar level of slowly degradable carbohydrate (average 294.5 g kg$^{-1}$ DM), which was higher ($P < 0.05$) than that of dehydrated pellets (173.3 g kg$^{-1}$ DM). All three lucerne products contained very little intermediately degradable carbohydrate, indicating the low starch content of lucerne (Table 1). This is in agreement with the NRC,[7] which reported that starch constitutes only 100 g kg$^{-1}$ of the non-structural carbohydrate in lucerne hay. Unavailable carbohydrate in the three lucerne products ranged from 170 to 213 g kg$^{-1}$ DM and was lowest ($P < 0.05$) for cubes, intermediate for dehydrated pellets and highest ($P < 0.05$) for sun-cured pellets.

### Protein composition of lucerne products according to the CNCPS

Crude protein content was highest ($P < 0.05$) for dehydrated pellets, intermediate ($P < 0.05$) for sun-cured pellets and lowest ($P < 0.05$) for cubes (Table 2). Lower CP levels for sun-cured pellets and cubes relative to dehydrated pellets were expected owing to the fact that sun-cured pellets and cubes were produced from a more mature material than dehydrated pellets. Other researchers have reported a decline in CP content as lucerne matures.[17,18] Sun-cured pellets had a higher ($P < 0.05$) soluble protein content than cubes (Table 2). However, no difference in soluble protein was observed between dehydrated and sun-cured pellets or between dehydrated pellets and cubes. Our soluble protein values are within the tabulated values (250–300 g kg$^{-1}$ CP) reported for alfalfa hay at different stages of maturity.[7] Lintzenich *et al*[3] also reported comparable soluble protein levels for dehydrated (259 g kg$^{-1}$ CP) and sun-cured (283 g kg$^{-1}$ CP) lucerne pellets.

Dehydrated and sun-cured pellets had similar non-protein nitrogen and neutral detergent-insoluble protein levels, which were higher ($P < 0.05$) than those of cubes (Table 2). Non-protein nitrogen constituted 900, 880 and 820 g kg$^{-1}$ of the soluble protein in dehydrated pellets, sun-cured pellets and cubes respectively. In agreement with our results, Mustafa *et al*[19] reported that 930 g kg$^{-1}$ of the soluble protein in lucerne hay is in the form non-protein nitrogen. The NRC[7] also reported non-protein values for alfalfa hay which are consistent with our values. Acid detergent-insoluble protein was higher ($P < 0.05$) for sun-cured pellets than for dehydrated pellets and cubes. Despite significant differences, the acid detergent-insoluble nitrogen values reported in this study for the three alfalfa products were relatively similar, irrespective of total CP content. This is in contrast with the tabulated values,[7] which show an inverse relationship between acid detergent-insoluble protein and total CP for alfalfa hay. However, in accordance with our findings, other researchers[3,20] reported no difference in acid detergent-insoluble nitrogen (average 60 g kg$^{-1}$ CP) as total CP of alfalfa hay decreases from 201 to 168 g kg$^{-1}$ (DM basis).

Sun-cured pellets had a lower ($P < 0.05$) total true protein content than cubes (Table 2). This is likely a combination of higher levels of non-protein nitrogen

| | Pellets | | | |
|---|---|---|---|---|
| | Dehydrated | Sun-cured | Cubes | SEM[a] |
| *Protein analysis* | | | | |
| Crude protein (CP) | 204.3a | 160.0b | 153.2c | 2.10 |
| Soluble protein (g kg$^{-1}$ CP) | 281.3ab | 316.4a | 251.5b | 12.40 |
| Non-protein nitrogen (g kg$^{-1}$ CP) | 253.4a | 277.4a | 206.3b | 8.61 |
| Neutral detergent-insoluble protein (g kg$^{-1}$ CP) | 324.1a | 331.1a | 273.5b | 11.11 |
| Acid detergent-insoluble protein (g kg$^{-1}$ CP) | 86.2b | 95.1a | 82.4b | 1.33 |
| *True protein fractions (g kg$^{-1}$ CP)* | | | | |
| Total | 660.7ab | 639.7b | 700.6a | 13.34 |
| B1 (rapidly degradable) | 27.9 | 31.2 | 34.9 | 6.20 |
| B2 (intermediately degradable) | 394.6b | 390.1b | 475.3a | 12.41 |
| B3 (slowly degradable) | 238.7a | 218.4b | 190.4c | 4.43 |

Means in the same row with different letters are significantly different ($P < 0.05$).
[a] Pooled standard error of the mean.

**Table 2.** Crude protein analysis and fractionation of lucerne products according to the Cornell Net Carbohydrate and Protein System (DM basis)

and unavailable CP for sun-cured pellets relative to cubes. No differences were observed in true protein content between cubes and dehydrated pellets or between cubes and sun-cured pellets. All lucerne products contained low and similar levels of rapidly degradable protein. Intermediately degradable protein was the main true protein fraction in the three lucerne products and was higher ($P < 0.05$) in cubes (475 g kg$^{-1}$ CP) than in dehydrated and sun-cured pellets (average 392 g kg$^{-1}$ CP). However, slowly degradable protein was lowest ($P < 0.05$) for cubes, intermediate ($P < 0.05$) for sun-cured pellets and highest ($P < 0.05$) for dehydrated pellets.

### Estimation of energy values

Total digestible nutrients[12] (TDN) and net energy of lactation were highest ($P < 0.05$) for dehydrated pellets (624.7 g kg$^{-1}$ DM and 5.90 MJ kg$^{-1}$ DM respectively), intermediate ($P < 0.05$) for cubes (559.0 g kg$^{-1}$ DM and 5.23 MJ kg$^{-1}$ DM respectively) and lowest ($P < 0.05$) for sun-cured pellets (548.7 g kg$^{-1}$ and 5.14 MJ kg$^{-1}$ respectively). The higher energy content of dehydrated pellets can be attributed to their higher protein and lower fibre levels relative to the other products. The estimated TDN value for dehydrated alfalfa in this study is similar to the *in vivo* value reported by Mustafa *et al*[21] (630 g kg$^{-1}$ DM). The TDN values for the three lucerne products are also consistent with tabulated values[7] for early bloom, full bloom and late bloom alfalfa hay (620, 560 and 530 g kg$^{-1}$ DM respectively). Our estimated values of net energy of lactation for the three alfalfa products are in good agreement with the values reported by the NRC[22] for mid-mature legume hay (5.0–5.3 MJ kg$^{-1}$ DM).

### Ruminal nutrient degradability

Results of the *in situ* experiment indicated that dehydrated pellets had the highest ($P < 0.05$) *in situ* soluble DM and effective DM degradability, followed by cubes and sun-cured pellets respectively (Table 3). Sun-cured pellets and cubes had a similar rate of degradation of the slowly degradable DM fraction, which was lower ($P < 0.05$) than that of dehydrated pellets. No differences were observed in slowly

| | Pellets | | | |
|---|---|---|---|---|
| | Dehydrated | Sun-cured | Cubes | SEM[c] |
| *Dry matter (DM)* | | | | |
| Soluble (g kg$^{-1}$ DM) | 330.2a | 234.2c | 270.4b | 3.49 |
| Degradable (g kg$^{-1}$ DM) | 500.1 | 549.1 | 533.7 | 12.03 |
| Degradation rate (% h$^{-1}$) | 4.3a | 3.1b | 3.4b | 0.25 |
| Effective degradability[b] (g kg$^{-1}$ DM) | 560.5a | 442.6c | 483.1b | 4.20 |
| *Crude protein (CP)* | | | | |
| Soluble (g kg$^{-1}$ CP) | 323.2a | 299.5b | 269.3c | 5.95 |
| Degradable (g kg$^{-1}$ CP) | 647.0 | 705.1 | 666.5 | 18.80 |
| Degradation rate (% h$^{-1}$) | 4.0a | 3.2b | 3.4b | 0.13 |
| Effective degradability[b] (g kg$^{-1}$ CP) | 611.4a | 556.4b | 554.7b | 3.91 |

Means in the same row with different letters are significantly different ($P < 0.05$).
[a] Derived from the equation of Ørskov and McDonald[14]
[b] Calculated assuming a ruminal outflow rate of 5% h$^{-1}$
[c] Pooled standard error of the mean.

**Table 3.** Ruminal dry matter and crude protein kinetic parameters[a] and effective degradability of different lucerne products

degradable DM fraction among the three lucerne products (average 528 g kg$^{-1}$).

*In situ* soluble CP was highest ($P<0.05$) for dehydrated pellets, intermediate ($P<0.05$) for sun-cured pellets and lowest ($P<0.05$) for cubes (Table 3). This is consistent with the chemical analysis, which showed higher buffer-soluble CP for dehydrated pellets than for the other products (Table 2). Rate of degradation of the slowly degradable CP fraction and effective CP degradability were similar for sun-cured pellets and cubes (average 3.3% h$^{-1}$ and 555.6 g kg$^{-1}$ respectively) and were lower ($P<0.05$) than those for dehydrated pellets (4.0% h$^{-1}$ and 611.4 g kg$^{-1}$ respectively).

The ruminal escape protein values of dehydrated pellets, sun-cured pellets and cubes, estimated from protein disappearance after 16 h of rumen incubation,[23] were 361, 420 and 498 g kg$^{-1}$ CP respectively. The results suggest that sun-cured pellets and cubes are better sources of ruminal escape protein (as a proportion of CP) than dehydrated pellets. The ruminal escape protein value of dehydrated pellets in the present study was lower than expected. Based on eight observations, the NRC[24] reported a ruminal escape protein value of 590 g kg$^{-1}$ CP for dehydrated lucerne hay. Our ruminal escape protein value for dehydrated pellets was also lower than the *in vivo* value reported for dehydrated lucerne hay by Loerch *et al.*[25] Differences in ruminal escape protein values of forages found in various studies can be attributed in part to the feeding regime employed for the fistulated animals. Ruminal escape protein values are usually determined using the *in situ* polyester bag technique with fistulated animals maintained on forage-based diets at or near maintenance level. Measuring ruminal escape of forage protein under these conditions may result in overestimated ruminal escape values for forage protein compared with situations where animals are fed high levels of concentrates.[26]

The low ruminal escape protein value reported in this study for dehydrated pellets may suggest that the heat input used during the dehydration process was insufficient to significantly reduce ruminal protein degradability. This was evident by the higher soluble CP content of dehydrated pellets relative to cubes and sun-cured pellets (Table 2). In agreement with our findings, Lintzenich *et al*[3] found that dehydration had little impact on protein solubility and degradability of lucerne used in their study. The authors speculated that in order to reduce energy expenditure, some lucerne dehydrators allow a greater degree of field wilting prior to the drying process. This will reduce the retention time of lucerne in the dehydrator and reduce the impact of heat on the ruminal undegraded protein content of dehydrated lucerne.

Based on our results and those of Linteznich *et al*,[3] it could be suggested that differences in ruminal protein degradability among the three lucerne products tested in this study were likely to have resulted from differences in maturity stage rather than from processing. Other workers[17,18] also reported reduced ruminal CP degradability of lucerne with increasing maturity.

## CONCLUSIONS

The results of the present study showed differences in chemical composition and ruminal degradability among the three lucerne products. Relative to sun-cured pellets and cubes, dehydrated pellets had higher protein and lower fibre levels. Consequently, the energy value of dehydrated pellets was higher than that of the other products. Dehydration had little impact on the ruminal escape protein value of dehydrated pellets, suggesting that suboptimal heat input was used during the drying process. The results of our study should be interpreted with caution owing to the confounding between stage of maturity and processing.

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# Dairy Nutrition Update for Forage Producers

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November 15, 2001

The new NRC Dairy Ration Model which was released in January 2001 consolidates a number of ideas on dairy nutrition that have been evolving over the past 10 years and introduces some new approaches to dairy ration formulation. Some of these changes should be of particular interest to forage producers and exporters in western Canada. This new NRC program is for ration evaluation and does not do least cost formulation. It covers the usual nutrients such as energy, protein, fiber, fat, dry matter intake, minerals and vitamins. In addition it gives some guidelines for meeting amino acid requirements and deals with nutrient levels for transition cows, calves, growing heifers, as well as dry and lactating cows. It also introduces some new considerations in feed processing and carbohydrate utilization.

The energy requirements are adjusted for environmental conditions and activity of the cattle. The heifer growth model is based on the 1996 Beef NRC program. One of the biggest changes in this program is the method of estimating and adjusting energy values of feeds. At present most feed analysis services estimate energy from chemical analysis of ADF or use infrared estimates. The 2001 NRC Dairy Model requires analysis for crude protein, ether extract, ash, ADF, ADF insoluble crude protein, NDF, NDF insoluble crude protein and lignin. A processing adjustment factor based on the rate of starch utilization was also included. Digestibility of the total ration is also considered. In addition net energy values are adjusted for level of feed intake. The higher the feed intake the lower the net energy value per kilogram of feed. In the case of forages digestibility of NDF is a major variable in estimating net energy values of forages.

The 2001 NRC model provides more specific guidelines for NDF requirements from forage. It suggests that it is possible to formulate rations with as little as 15% NDF from forage provided there is a total of 33% NDF to the ration with the additional NDF coming from byproduct feeds. This concept and its application in a number of countries may have profound effects on Canadian forage exports. It will be necessary to take into account the use of high fiber non-forage ingredients such as citrus pulp, whole cottonseed, cottonseed hulls, soybean hulls, tomato pulp, almond hulls, peanut hulls, and poultry litter in dairy rations. There is still a role for Canadian forages in these rations, however it must be carefully described. Physical characteristics such as density of forage may also be important.

There has been a great deal of interest in forages as a source of sugars. Sugars provide instant energy for rumen microbial growth and must be matched by readily available nitrogen sources. Sugar content has also been associated with good palatability. There are a number of methods for measuring sugars in forages in addition to the direct measurement of free sugars. Fraction A of the Cornell Net Carbohydrate and Protein System is a good measure of readily available sugars, as is the new Florida methodology and the as yet untested methods for measuring carbohydrate fractions in diets for diabetics.

Evaluation of dairy rations for amino acid content is becoming common practice. Although the amino acid requirements are not known with great certainty it has been established that lysine as a percent of metabolizable protein should be over 7% (6.5% of crude protein) and methionine should be above 2.4% of metabolizable protein (2.1% of crude protein) to obtain maximum milk protein yield. One concern is the highly variable estimates of lysine and methionine in forages.

The new NRC system assumes that feeds do not contribute any vitamins and that all vitamins must be provided in supplementary form. Another change is that mineral requirements are estimated as available minerals. Calcium in forages is estimated to be 30% available and phosphorus 64% available.

Canadian forages will continue to be a high quality source of fiber, energy, protein, minerals, and vitamins. Some new description of forages may be required for both domestic and export markets. Meat consumption is expected to increase in Asian countries and will continue to be important. Canadian forages will be used to a greater extent in combination with high fiber byproducts ingredients.

# Dairy Nutrition Update for Forage Producers

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## NRC Dairy 2001 CD ROM

## Subjects Covered

- Dry matter intake
- Energy
- Fat
- Fiber / NFC
- Protein and AA
- Minerals
- Vitamins
- Water
- Transition cows, metabolic disorders, performance modifiers
- Young calf
- Growing Heifer
- Nutrients and environment
- Feed processing and carbohydrates

## Management, Environment

Lactating/Dry Cow

- Temperature
- Grazing information
  - Topography
  - Distance walked information

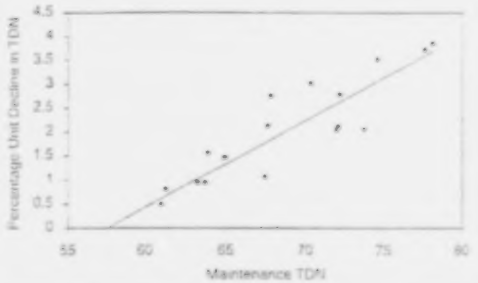
Heifer

- Temperature
- Previous temp
- Wind speed
- Grazing
- Coat condition
- Heat stress
- Hair depth
- Night cooling

## Composition of Dehy Alfalfa and Timothy Hay in the 2001 NRC Dairy Model Database

| | Dehy Alfalfa | Timothy Hay |
|---|---|---|
| | % in Dry Matter | |
| Crude protein | 19.2 | 10.8 |
| Ether extract | 2.5 | 2.0 |
| Ash | 11 | 7.0 |
| ADF | 32.8 | 41.6 |
| ADFICP | 2.4 | 1.1 |
| NDF | 41.6 | 69.1 |
| NDFICP | 3.1 | 7.4 |
| Lignin | 7.6 | 5.9 |
| Processing factor | ? | 1.0 |
| NDF digestibility | 37 | 48 |
| NEl, Mcal/kg | 1.25 | 1.14 |

## Energy Discount Based on Intake (2 times Maintenance)



## Forage Energy Values Vary with Level of Intake and Digestibility of NDF in the 2001 NRC Dairy Model (Ration contains 74% TDN in DM)

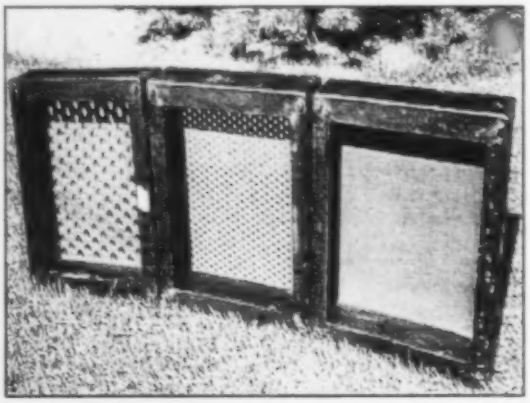
| | Dehy Alfalfa | | | Timothy Hay | | |
|---|---|---|---|---|---|---|
| Digestibility of NDF, % | 37 | 45 | 55 | 48 | 52 | 57 |
| Intake, x maintenance | 3 | 3 | 3 | 3 | 3 | 3 |
| TDN, % | 56 | 60 | 64 | 52 | 55 | 58 |
| NEl, Mcal/kg | 1.25 | 1.34 | 1.45 | 1.14 | 1.22 | 1.31 |
| Intake, x maintenance | 1 | 1 | 1 | 1 | 1 | 1 |
| TDN, % | 62 | 66 | 71 | 57 | 61 | 65 |
| NEl, Mcal/kg | 1.40 | 1.50 | 1.63 | 1.28 | 1.38 | 1.47 |

## Fiber Requirements

- 1989
  - 25 to 27% NDF
  - 75% from forage (19 to 20% of DM)
- 2001
  - 25 to 33% NDF
    —Function of forage NDF
  - 19% fNDF = 25% total NDF and max. 44% NFC
  - 15% fNDF = 33% total NDF and max. 36% NFC

## The Feasibility of Low Forage Dairy Rations

- Israel rations may contain only 30% forage (45% is the usual minimum in Canada)
- These rations usually contain not less than 30 to 33% NDF and 18% ADF
- High fiber non forage ingredients
  - poultry litter
  - citrus pulp
  - whole cottonseed
  - cottonseed hulls
  - soybean hulls
  - tomato pulp
  - almond hulls
  - peanut hulls
- Asian dairy researchers are visiting and studying Israeli ration strategies
- Israeli rations usually contain 5 to 10% alfalfa and some grass or cereal hay or silage



## Forage Characteristics and Rumen Health

- **Particle size in a TMR**
  — Not more than 60% of TMR less than 8 mm
- **Forage and fiber source density**
  — particles should float in the rumen to provide effective fiber

## Forages as a Source of Sugars

- Instant energy for rumen microbes
- Effect on palatability
- Free sugars can be measured by standard lab methods
- Measured as carbohydrate fraction A in the Cornell System
- Measured using the medical system for measuring carbohydrate fractions for dietary control of diabetes
- Measured using the Florida (Mary Beth Hall) carbohydrate system

## The Cornell Net Carbohydrate and Protein System Utilization in the Rumen

- Used in the CNCPS (1992)
  - CPM Dairy Model
  - US-NRC 1996 Beef Model
  - US-NRC 2001 Dairy Model
- Fraction A; rapidly fermented sugars
- Fraction B1; starch, pectin, βglucans
- Fraction B2; fermentable cell wall
- Fraction C; unavailable cell wall

## Amino Acid Requirements

- Requirements are not well known
- NRC 2001 estimates flow of AA
- On average milk protein decreases when:
  - Lysine in Metabolizable Protein is below 7% (6.5% of CP)
  - Methionine in MP is below 2.4% (2.1% of CP)

## Lysine and Methionine as Percent of Crude Protein

| | NRC 2001 | | CPM Dairy | | NRC Swine | | Joint US-Can | |
|---|---|---|---|---|---|---|---|---|
| | Lys | Meth | Lys | Meth | Lys | Meth | Lys | Meth |
| Dehy Alfalfa | 3.43 | 1.46 | 6.02 | 0.73 | 4.35 | 1.47 | 4.92 | 1.53 |
| Blood meal | 8.98 | 1.17 | 9.34 | 1.07 | 8.46 | 1.12 | 7.94 | 1.11 |
| Barley Grain | 3.63 | 1.70 | 3.07 | 0.81 | 3.62 | 1.77 | 3.28 | 1.26 |
| Canola Meal | 5.62 | 1.87 | 6.67 | 1.40 | 5.84 | 2.08 | 5.37 | 1.92 |
| Corn Grain | 2.84 | 2.13 | 1.65 | 1.12 | 3.13 | 2.05 | 2.40 | 2.10 |
| Corn Gluten Meal | 1.69 | 2.37 | 1.24 | 2.09 | 1.69 | 2.37 | 1.67 | 2.95 |
| Corn Silage | 2.51 | 1.53 | 2.13 | 0.80 | - | - | 5.18 | 5.30 |
| Grasses | 3.46 | 1.37 | 2.83 | 0.67 | - | - | 10.30 | 2.07 |
| SBM | 6.27 | 1.45 | 6.08 | 0.83 | 6.35 | 1.41 | 7.21 | 1.42 |

## Mineral Availability; Forages and Concentrates

| Mineral | Availability % | Mineral | Availability % |
|---|---|---|---|
| Calcium, Forages | 35* | Sulfur | 100 |
| Concentrate | 60 | Cobalt | 100 |
| Phosphorus, Forages | 64* | Copper | 4 |
| Concentrate | 70 | Iodine | 95 |
| Magnesium | 18 | Iron | 10 |
| Chloride | 90 | Manganese | 0.75 |
| Potassium | 90 | Selenium | 100 |
| Sodium | 90 | Zinc | 15 |

## Summary

- Net Energy in a feed varies with nutrient composition, level of feed intake and energy content of the ration
- NDF requirement goes up as long forage intake goes down in the ration
- Carbohydrate fractions (including sugars) are used to predict microbial protein and amino acids
- Amino acid estimates in forages are not reliable
- Model is very good for ration evaluation

## Canadian Export Forages

- To support the livestock revolution in forage deficient countries
- A high quality source of fiber, energy, protein, minerals and vitamins
- Few concerns about residues and heavy metal contamination
- Used in combination with high fiber byproduct feeds

# The Role of Forages in Food Security and Safety

D.A. Christensen
Dept. of Animal & Poultry Science
November 15, 2001

As world population grows and urbanization continues to take place, food security and food safety are of increasing concern. Globalization and technological change may benefit certain segments of the food supply chain but there is concern for those that will be disadvantaged. The structure of farming is changing rapidly with small farmers changing occupations, often with a move to an urban area. Large scale farming tends to become concentrated near larger cities. There is also a shifting role for government in relation to industry in directing economic planning.

As urbanization takes place and incomes rise it is expected that there will be a livestock revolution over the next 25 years in which livestock product consumption will increase replacing some of the grain in the human diet. This increase in demand for meat products will place great stress on grazing lands and on forage resources in many countries. Intensive livestock production is likely to develop close to the expanding urban areas. Milk consumption is expected to increase by 3.3% per year or by 227 million metric tonnes per year, by 2020. Most of this will occur in developing economies such as China and Southeast Asia where milk consumption is expected to triple in China and double in Southeast Asia. Meat consumption is also expected to nearly double in China with 25% of this increase being in beef products. The increase in meat consumption of 100 million metric tonnes is expected to demand an additional 290 million metric tonnes of cereal grains by 2020 and an increase of at least 100 million metric tonnes of forages.

Together with an increased demand for high quality livestock products there is also concern about the distribution of this food and the risks that maybe associated with the food industry. At present 33% of all children under 5 years of age are stunted due to malnutrition and 24% of all newborns have impaired growth and development due to poor fetal nutrition. It is expected that there will be some increase in child and infant nutrition over the next 20 years, however it will remain a significant problem.

There are growing concerns about risks associated with foods due to bacteria, virus, parasites, as well as contamination of animal feed and foodstuff with a variety of compounds such as insecticides and non-food lubricants as well as the possibility of terrorist actions. As a result of these concerns identity preservation of animals feed and food crops will become a growing necessity. This will require segregation and traceability of livestock feeds in addition to genetic identification. Some of these

aspects are now in place through animal identification systems, identification of feeds with novel traits (GMO,s), HACCP, and ISO 9000.

The effect of livestock on the environment is also of concern. At present livestock graze on about 26% of the world's land area and about 20% of these grazing lands (680 million hectares) have been degraded. Very few countries have the potential to increase grazing land area or productivity. This has led to the development of strategies to replace forages with high fiber byproducts and crop residues. Intensive agriculture production systems have also had undesirable fates on the environment. In Asia there is wide spread nitrogen contamination of water and government policies in some countries have resulted in the overuse of fertilizer and contamination of both food and water with nitrates and phosphates. In some cases the soil has been become contaminated with heavy metals, pesticide and herbicide residues that escape the minimum testing procedures.

There should be optimism about Canada's ongoing ability to export forages. This is based on a need for forages in the coming livestock revolution in forage deficient countries. Canadian forages will continue to be identified as high quality sources of fiber, energy, protein, minerals and vitamins. Canadian forage sources should have a few concerns about residues and heavy metal contamination. It is also necessary for Canadian exporters to develop strategies to use high quality Canadian forages in combination with high fiber byproducts.

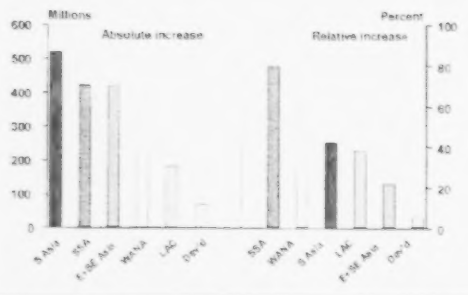
# The Role of Forages in Food Security and Safety

David Christensen
Dept. of Animal & Poultry Science
University of Saskatchewan
Saskatoon SK Canada

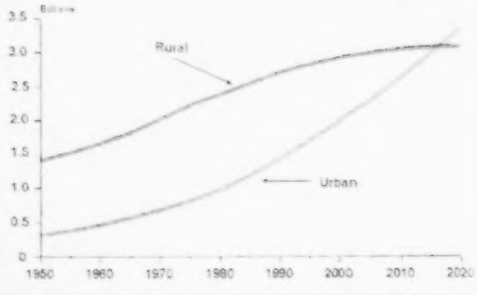
## Influences on Global Food Security

- Globalization, trade liberalization (who will lose)
- Technological change
- Degradation of soil and water
- Health and nutrition crises
- Rapid urbanization
- Changing structure of farming
- Continued or expanded conflict (terrorism)
- Climate change
- Changing role of key actors (government, industry, corruption)

## World Population Increases 1995-2020



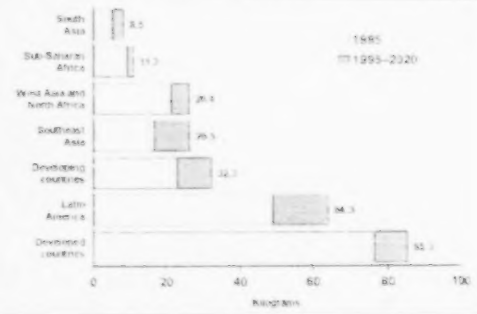

## Urban and Rural Population in Developing Countries, 1950-2020



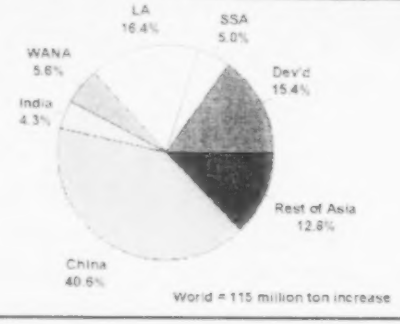

## The Livestock Revolution

- Rapid world wide increase in consumption of livestock products
- Increased share of livestock consumption in developing countries
- Larger scale livestock operations, technology change
- Meat and milk replacing grain in the human diet
- Increased demand for cereal based feeds
- Stress on grazing and forage resources
- Intensive livestock production closer to cities

## Per Capita Demand for Meat Products 1995-2020



## Share of Increase in Global Demand for Meat Products, 1995-2020




## Milk and Meat Consumption
kg/person

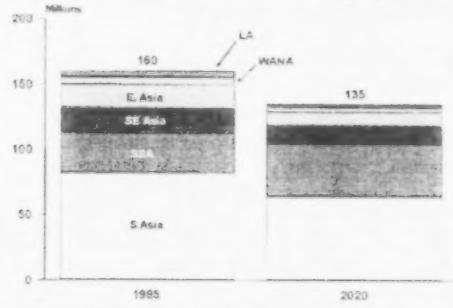
| | Milk | | Meat | |
|---|---|---|---|---|
| | 1997 | 2020 | 1997 | 2020 |
| Developed world | 260 | 270 | 75 | 80 |
| China | 4 | 12 | 45 | 70 |
| South East Asia | 7 | 12 | 20 | 35 |
| South Asia | 100 | 120 | 6 | 10 |
| Latin America | 125 | 145 | 53 | 68 |

Impact model, June 2001

## Nutrition and Health

- Of the worlds 6 billion people, about 800 million are malnourished
- 33% of all children under 5 years of age are stunted
- 24% of all newborns have impaired growth and development due to poor fetal nutrition
- 2 billion people suffer from anemia
- Many people have low intakes of vitamin A, zinc and iodine

## Number of Malnourished Children 1995 and 2020




## Risks Associated with Foods

In the USA up to 33 million people (12%) become ill from food (mainly microorganisms) every year

- Bacteria, viruses, parasites
- Glass, metal fragments, packaging material
- Non food lubricants
- Cleaning compounds
- Food additives
- Insecticides
- Terrorist actions

## Feed and Food Passports?

- Identity Preservation of animals, feed and food crops
  - Genetic identification
  - Segregation
  - Traceability, tracking a forage from field through feeding to food products

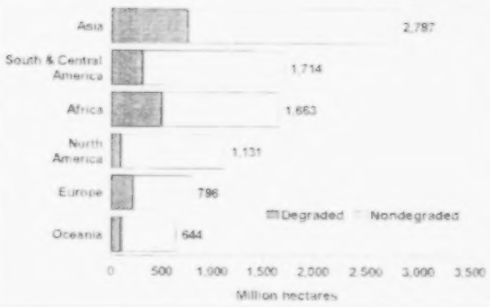
Now partly in place through animal identification systems and identification of novel traits (GMO)
Includes HACCP and ISO 9000

## Livestock and the Environment

- Livestock graze on about 26% of the world's land area
- Since 1945 about 20% of grazing lands (680 m/ha) have been degraded
- Limited potential to increase grazing land productivity
- Forage is being replaced with byproducts, and crop residues

## Overgrazed Pasture

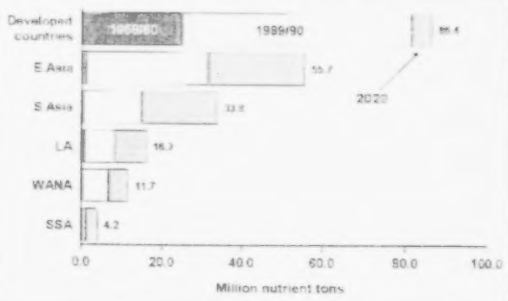
## Global Estimates of Soil Degradation




## Effects of Intensive Agriculture on Food and Water Quality in China

- Nitrogen contamination of water
- Excessive application of fertilizer by government policy
  - food and water nitrates
- Soil and food contamination with heavy metals (lead, mercury) from poor quality fertilizer
- Pesticide and herbicide residues (minimal testing)
- Microbial contamination

## Global Fertilizer Use 1959/60, 1989/90 and 2020




## The Livestock (Meat) Revolution

- In the developed world over the next 20 years
  - meat consumption will increase 0.6% annually (16 mmt)
  - milk will increase 0.2%/year (13 mmt)
- In the developing countries
  - meat will increase 2.8%/year (100 mmt, from 88 to 188 mmt)
  - milk will increase 3.3%/year (227 mmt)
  - at least 100 mmt of forage
- The world will need an additional 290 mmt of feed grains by 2020
  - inflation adjusted prices of livestock and feed commodities will continue to fall, though not as rapidly as during the past 20 years

## Canadian Export Forages

- To support the livestock revolution in forage deficient countries
- A high quality source of fiber, energy, protein, minerals and vitamins
- Few concerns about residues and heavy metal contamination
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